Vol. XLV. JUNE, 1901.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

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By G. N. HOUSTON, Assoc. M. Am. Soc. C. E.

PRESENTED FEBRUARY 20TH, 1901.

WITH DISCUSSION.

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advising the water company to filter the supply. Nothing, however, was done at that time.

In July, 1897, the Village of Nyack acquired the plant of the Nyack Water-Works Company by condemnation proceedings, and began to consider the improvement of the supply.

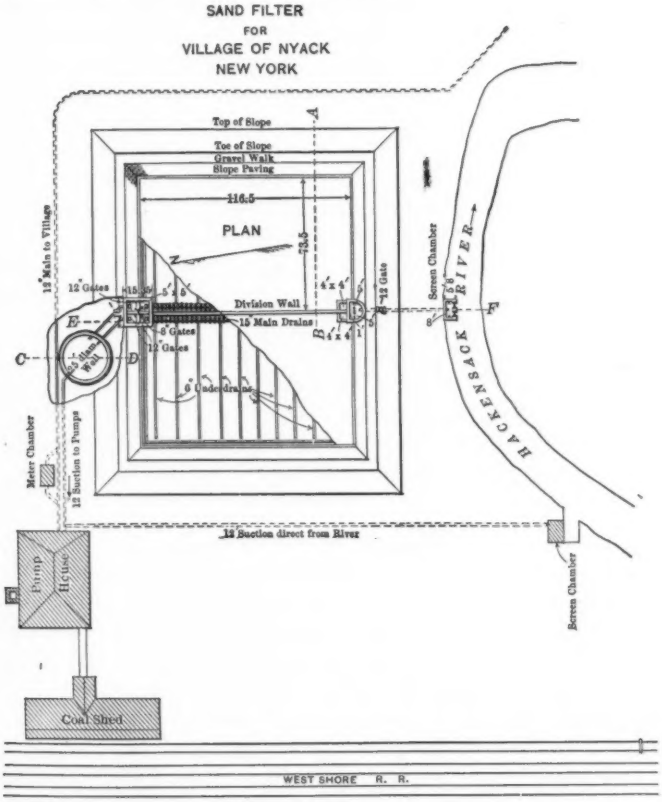

FIG. 1.

Driven wells were tried and failed. A gravity supply from a more sparsely settled water-shed was considered, but the estimated cost exceeded the available means. The filtration of the present supply was then recommended and adopted.

Description of Plant.

The filter is of the open, gravity, sand type, and was designed for slow filtration. It is located in a swamp on the Hackensack River, about 2½ miles west of the village, and just north of the West Nyack Station on the West Shore Railroad (Fig. 1).

It consists of two rectangular beds of equal size, with a combined filtering area of 16 400 sq. ft., or 0.38 acre, and a pure-water reservoir having a capacity of 44 000 galls. It is built wholly in excavation below the level of the creek, and is protected by earth embankments from high water, which floods the surrounding ground. Several cross-sections are shown in Fig. 2.

The enclosing walls are of concrete to a height of about 3 ft. 8 ins. above the bottom. Above these walls a vitrified brick paving is laid at a slope of 1½ to 1, and to a height of 4 ft. above the wall.

The bottom is of concrete, and the regulating and intake chambers are of brick. The division wall above the sand is of brick; below the sand it is of concrete.

The filtering material consists of 3 ft. of sand underdrained by 1 ft. of gravel and by 6-in. tile pipe. Each bed has a main drain of tile pipe leading to the regulating chamber.

The pure-water well is built of brick, and the bottom is of concrete. It is entirely separated from the filter, but is connected with the regulating chamber by a 12-in. cast-iron pipe.

Details of Construction.

The excavation was begun during dry weather of August, 1897. After removing 2 ft. of black muck on top, a stiff damp red clay was encountered, and the deeper the excavation was carried, the more wet and tenacious became the clay, and the more difficult it became to handle. Shovels and spades were used to cut it in blocks which were then thrown on wagons by the hands. Teaming was impossible, except on roadways of old railway ties or plank.

The depth of the cut to be made averaged 12.5 ft. After a depth of 10 ft. was reached, the sides of the excavation, which up to this time had stood nearly vertical, cracked back from the face a distance of 2 to 4 ft., and subsided, making a corresponding elevation in the adjacent bottom, which had become very soft and puddled by teaming over it.

To remedy this difficulty, excavating the easterly end at a slope of 1½ to 1 was tried, with a like result when the same depth was reached,

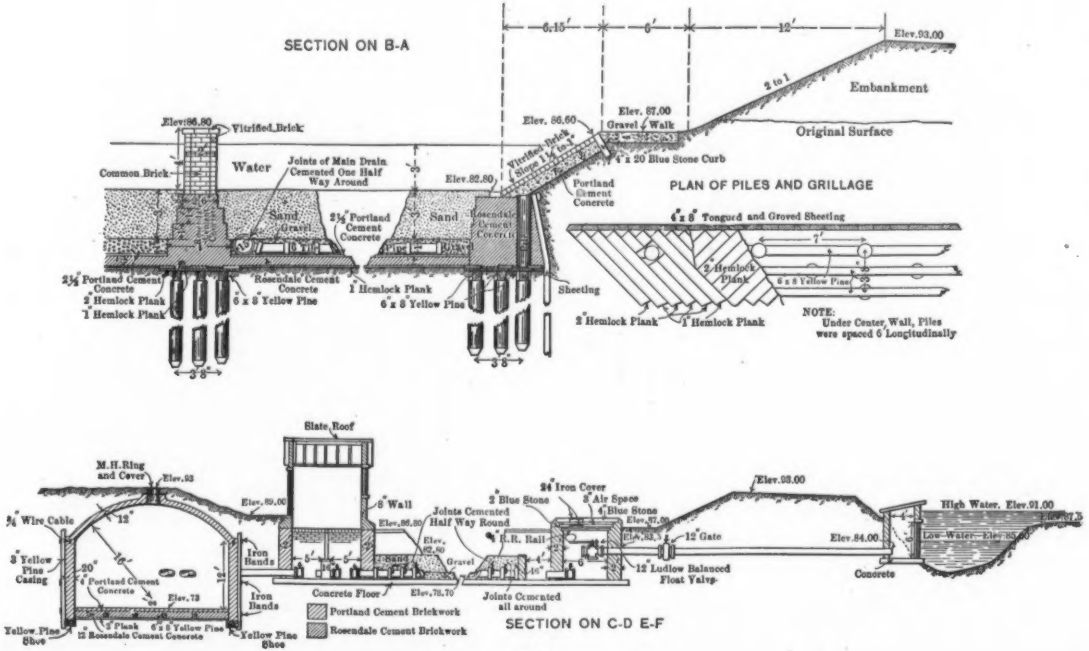
SECTION ON B-A
6.15'
0'
12'
Elev. 93.00
2 to 1
Embankment
Original Surface
Elev. 87.00
Gravel Walk
Elev. 86.60
Vitrified Brick
Elev. 86.80
Vitrified Brick
Common Brick
Water
Joints of Main Drain Cemented One Half Way Around
Elev. 82.80
Vitrified Brick (Stone 1 1/4" to 1')
4" x 20" Blue Stone Curb
Portland Cement Concrete
Sand
Gravel
2 1/2" Portland Cement Concrete
Rosendale Cement Concrete
Sand
Rosendale Cement Concrete
Brick
Brick
2 1/2" Portland Cement Concrete
2" Hemlock Plank
1" Hemlock Plank
Rosendale Cement Concrete
6" x 8" Yellow Pine
1" Hemlock Plank
6" x 8" Yellow Pine
Sheeting
PLAN OF PILES AND GRILLAGE
6" x 8" Tongued and Groved Sheeting
7'
2" Hemlock Plank
6 x 8 Yellow Pine
2" Hemlock Plank
1" Hemlock Plank
NOTE:
Under Center Wall, Piles were spaced 6' Longitudinally
Slate Roof
M.H. Ring and Cover
Elev. 93
Elev. 89.00
6" Wall
Joints Cemented Half Way Round
Elev. 86.80
Elev. 82.80
24" Iron Cover
2" Blue Stone
2" Air Space
4" Blue Stone
Elev. 87.00
Elev. 93.00
High Water, Elev. 91.00
3/4" Wire Cable
12"
3" Yellow Pine Casing
20"
4" Portland Cement Concrete
Elev. 73
Iron Bands
Iron Bands
Gravel
R.R. Rail
12" Gate
Elev. 84.00
Low Water, Elev. 85.00
12" Ludlow Balanced Float Valve
Concrete
Concrete Floor
Elev. 78.70
Joints Cemented all around
Yellow Pine Shoe
1" Plank
6 x 8 Yellow Pine
12" Rosendale Cement Concrete
Yellow Pine Shoe
Portland Cement Brickwork
Rosendale Cement Brickwork
SECTION ON C-D E-F

FIG. 2.

and it became evident that, with this method of excavation, the required depth could not be reached.

The contractor had taken the excavation at the low price of 29 cents per cubic yard. It was evident that he was losing money on this part of the work, and, becoming somewhat discouraged, he finally abandoned it.

Rudolph Hering, M. Am. Soc. C. E., was then asked to report on the situation for the village. By his advice, soundings were made over the entire area. These were made with an iron rod 1 in. in diameter and 30 ft. long, on which was arranged a sliding weight. This weight was made of a short section of 6-in. cast-iron water pipe, in the center of which was a piece of 1¼-in. wrought-iron pipe, the space between being filled with lead. On the bottom was an iron plate, the whole weighing about 130 lbs.

The weight was lifted by two men and allowed to fall on an adjustable clamp. The height to which it was lifted varied from 3 to 4 ft., and a record was taken of the depth penetrated by each ten blows. The upper part of the rod was steadied by a tripod. To withdraw the rod a 3-ton block and fall was used.

These soundings showed the presence of water-bearing gravel strata varying from 2 ft. at the westerly end to 20 ft. at the easterly end below the proposed bottom of the filter. Mr. Hering then advised continuing the construction by the use of sheet-piling and sustaining piles.

Before the sheet-piling could be started, the creek broke through the bank and flooded the excavation. This made it necessary to drive a line of 4 x 8-in. tongued and grooved spruce sheeting between the creek and the excavation. This sheeting was driven to a depth of 3 to 4 ft. below the proposed bottom of the filter. The water was then pumped out, and the whole area surrounded by a single row of sheet-piling of the same kind. The latter sheeting was driven within the excavation and 1 ft. outside of the foundation line of the filter. Sustaining piles were then driven on the proposed site of the walls.

In driving the sheeting it was found that in most places it could be driven clear through the gravel strata into softer material below. For this reason the round piles were driven with blunt ends of at least 6 ins. diameter. Although some of the 332 piles thus driven evidently stopped at the gravel strata, fully two-thirds of the number depend largely on friction for sustaining power.

The maximum weight sustained by each pile under the outside wall

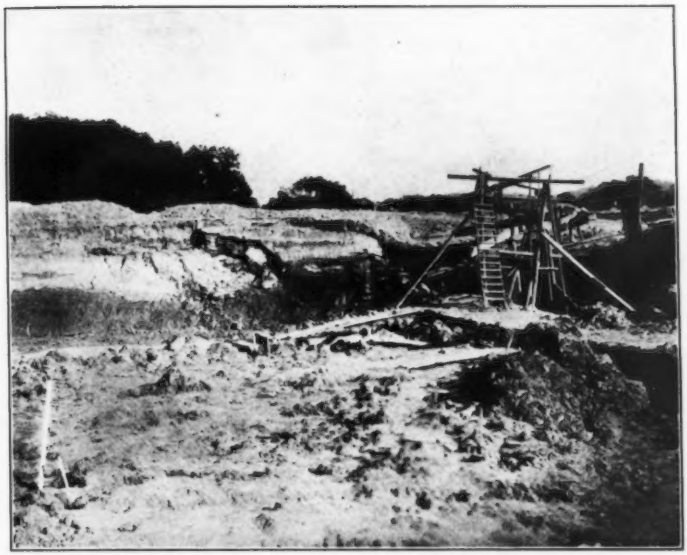

FIG. 1.—VIEW OF EXCAVATION, SHOWING SUBSIDENCE OF BANKS.

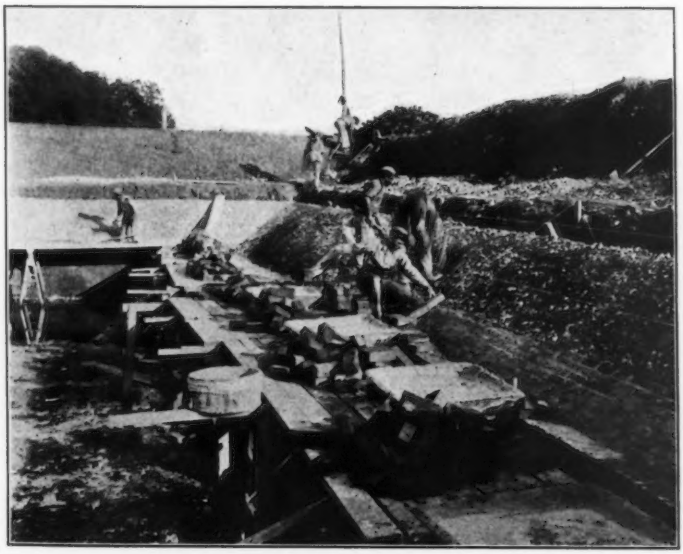

FIG. 2.—LAYING VITRIFIED BRICK SLOPE.

is about 4 tons; under the division wall, 5½ tons. The sheeting cost 5 cents per foot, board measure, driven, and the cost of the sustaining piles averaged $4.42 each, in place.

Just at this time, April, 1898, the funds available for this work gave out and the construction came to a standstill. Soon after, during high water, the excavation was flooded a second time. It remained in this condition until July, 1899, when the work was again taken up.

The original plans and specifications were modified to meet the new conditions, and a new contract was let. The changes were as follows:

First.—The level of the whole bed was raised 1 ft., and the depth of the filtering material was reduced from 5 to 4 ft. This made a total raise of 2 ft. in the bottom of the filter, and reduced the average cut to 10.5 ft.

Second.—Concrete was substituted for brickwork in the walls below the level of the top of the sand, and slope paving was substituted for the vertical walls above this level.

Third.—All brickwork exposed to the elements was faced with vitrified brick.

After pumping out the water, the excavation was carried down to the proper depth on the site of the outside walls, the piles were sawed off and capped, and the walls were started before attempting to excavate the interior.

The sheet piling was exposed by this excavation for a depth of 5 to 7 ft., and was seen to be practically water-tight. It had a tendency to crowd in at the top, on account of the pressure behind it, and, in order to brace it, the outside row of sustaining piles was left standing. Inclined braces, running to a footing of railroad ties, were also found necessary.

In one place, where the sheeting had been pushed over so far as to interfere with proper construction, it was forced back part way by screw jacks after relieving some of the pressure by excavating behind it.

At the easterly end derricks and buckets were used to handle the excavated material and to place the concrete, but were not found necessary after the wall at that end was completed. The interior was excavated with teams. Very little water was encountered until the walls and floor of the east half were nearly completed, when a large spring broke out in the center of the excavation at a point over which all the teams bringing material for concrete had passed and had con-

sequently puddled the clay. This was stopped at this point, but broke through at a point about 20 ft. distant.

Underdrains were laid leading the water to the pure-water well, which had been sunk to a depth somewhat lower than the filter, and was kept dry by a centrifugal pump.

This and a similar spring which broke through later were left until the beds were otherwise completed, and were finally stopped by filling with from 10 to 12 cu. yds. of field stone and concreting over it, leaving a 15-in. vitrified pipe through the concrete for a drain. When the concrete had set, a 6-in. pipe was placed inside the 15-in. pipe, and bagging was rammed down around it and loaded with concrete, which was covered with bagging, to prevent the water which dropped over the edge from washing out the cement. It was found that there was not head enough to raise this water above the sand line, and the spring was stopped up with cement bags and concrete.

The piles were capped with 6 x 8-in. yellow pine stringers spiked to each pile by two 14-in. drift bolts. Where the ends of these stringers met they were joined with a scarf joint and bolt and nut.

The piles in the row next to the sheeting were notched to receive the stringers, as shown in Fig. 2. On these stringers, and at an angle of 45° with them, 2-in. hemlock planks were nailed. On top of these, and at an angle of 90° with the former planks, were nailed 2-in. and 1-in. hemlock plank, laid alternately, thus making a well-braced platform sufficiently rough to give a good footing for the walls.

The cost of the piles, capping and platform averaged $3 per foot of wall sustained.

The forms for the walls were then erected. They were made from 2-in. hemlock plank. In some instances forms were used for the back of the wall, but in most of the construction the concrete was carried back against the sheeting, and the piles in the outside row were concreted into the wall.

In some instances the inclined braces supporting the sheeting were also concreted into the wall and left until just previous to putting in the sand, when they were either taken out and the hole filled up with concrete, or sawed off and cut back from the face of the wall at least 6 ins. and covered with Portland cement concrete.

The face of the outside walls below the sand line was stepped in 2 ins., and the division wall 3 ins. in each foot of rise. With the excep-

FIG. 1.—PLACING GRAVEL IN EAST FILTER BED.

FIG. 2.—UNDERDRAINS AND MAIN COLLECTOR IN WEST FILTER BED.

tion of the division wall, which was of uniform dimensions throughout, the concrete walls varied in thickness according to their location. The concrete in the south wall averaged 0.8 cu. yd. per lineal foot; that in the east wall averaged 0.33 cu. yd. per lineal foot, and that in the north and west walls 0.7 cu. yd. per lineal foot. The division wall averaged 0.61 cu. yd. per lineal foot.

The floors were placed on 1-in. hemlock plank, laid on the clay to prevent the concrete from mixing with the soft bottom.

They were made of Rosendale cement concrete 0.66 ft. thick, topped with Portland cement concrete having an average thickness of 0.22 ft.

All concrete was mixed by hand. Rosendale cement concrete for the walls and floor was composed of 1 part cement, 2 parts sand and 6 parts broken limestone, varying from ½ in. to 2½ ins. in greatest dimensions. The Portland cement concrete in the floors was mixed in the proportions of 1 part cement, 3 parts sand and 5 parts ¾-in. broken limestone.

The faces of the concrete walls were first pointed up with 2 to 1 Rosendale cement, and then plastered with 2 to 1 Portland cement.

The floors cost $1.50 per square yard in place. The concrete walls cost $4.40 per cubic yard in place. The labor of mixing and depositing the concrete for the walls was 1 man, 0.42 day per cubic yard. For the Rosendale cement concrete in the floors, 1 man, 0.32 day per cubic yard.

The division wall, above the sand line, was built of brick in Portland cement, and faced with vitrified brick. The slope paving was laid on a foundation of 8 ins. of Portland cement concrete, composed of 1 part cement, 3 parts sand and 7 parts broken limestone, varying from ½ in. to 2½ ins. in greatest dimension. The vitrified brick slope paving and all other brickwork, with the exception of that in the house over the regulating chamber, was laid in 3 to 1 Portland cement mortar.

The average cost of the exterior concrete wall, slope paving and curb was $5 per lineal foot. The average cost of the division wall was $5.19 per lineal foot. The ordinary brickwork in the walls cost $8 per cubic yard. The vitrified brickwork in the walls cost $8.40 per cubic yard.

The intake chamber extends outside of the first row of sheeting, and is of circular form on the outside, to better withstand the pressure.

The filtering gravel is of the following sizes: The bottom 6 ins. in depth varies from 3 ins. to 1 in. in greatest diameter; the next 3 ins.,

from 1 to ½ in.; the top 3 ins., ½ in. and less. With the exception of a small portion of the top layer, the gravel in the east half is of crushed trap rock and hard field stone; in the west half it is washed gravel from Cow Bay, Long Island.

The sand was obtained from Cow Bay, and was delivered in barges at the dock at Nyack, from which it was carted to the beds in wagons. It was placed in the beds as received, as was also the crushed stone and gravel. Both sand and gravel cost $2.15 per cubic yard in place.

During the first week the filter was operated the water was wasted, on account of its being quite turbid and tasting of the cement. After that, it was pumped into the reservoirs, although still quite turbid. After about a month it became decidedly better, and at the end of the second month the turbidity could scarcely be noticed in an ordinary glass, but still showed slightly in the regulating chamber, where there was a depth of about 8 ft.

After three months the water was free from all turbidity, but had a slight color. In a glass or small vessel it appeared to be colorless, but where there was any considerable depth, as in the regulating chamber, it could be easily noticed.

In the intake chamber there is an ordinary 12-in. Ludlow balanced float valve, which regulates the depth of water over the sand to 3 ft., when the pumps are running; otherwise, 3½ ft.

The rate of filtration is regulated by the pumps, which draw from the pure-water well and supply the reservoirs in the village. The pumps are in use almost every day for at least 9 hours, and run at a uniform rate while in operation.

The maximum consumption of water is at the rate of about 630 000 galls. per day, which, if one bed only were used, would give a maximum draft of about 3 326 000 galls. per acre per day. This condition, however, is not realized in practice, as both beds are used at the same time, except when one is being cleaned.

The development of the springs before mentioned is reducing to some extent the amount of filtered water required, and the total consumption is being decreased by the gradual introduction of meters.

The pure-water well was sunk on a shoe made of three rings of 4-in. yellow pine bolted together. Each ring is composed of six sections. This makes a solid shoe of 25 ft. internal and 28.5 ft. external diameter.

An excavation, about 6 ft. deep, was made on the site of the well,

FIG. 1.—PLACING SAND IN EAST FILTER BED.

FIG. 2.—COMPLETED FILTER BASINS AND REGULATING CHAMBER.

and the shoe was put together in the bottom. Around this shoe was erected a tub or casing of 3 x 6-in. x 15-ft. yellow pine plank, spiked to the shoe and held in place by three iron hoops drawn tight by bolts and nuts. The 20-in. wall was then built on this shoe to a height of 10 feet.

Excavation with derricks and buckets was then begun, but, later, the second contractor erected a centrifugal pump, and, using a jet of water from the mains under about 150 lbs. pressure, softened the clay and pumped it out.

The floor was made by laying 2-in. planks on the bottom, and over them 6 x 8-in. yellow pine timbers, inserted in holes cut in the brick-work just above the shoe. Rosendale cement concrete 1 ft. thick and of the same character as that on the bottom of the filter, was then laid on the bottom, thus covering the 6 x 8-in. stringers 4 ins. deep. On this a 4-in. layer of Portland cement concrete was placed.

The well was covered with a spherical dome of 6 ft. rise, the radius of the sphere being 16 ft. To relieve the thrust of this dome, a $\frac{3}{4}$-in. cable was built in at the spring line. Of this cable, 125 ft. were used, it being double on the side toward the filter.

The embankments were formed with the material excavated from the original surface, without cleaning or grubbing. Where it was found necessary to make embankments upon which the slope paving was to rest great care was taken to have it thoroughly compacted by tamping and then settling with water. Nothing was done to compact the embankments above the slope paving, except the ordinary teaming over them. They were designed and constructed originally on a slope of $1\frac{1}{2}$ to 1, with the walk 1 ft. above the curb. They were completed about December, 1899, and, therefore, could not be seeded. The clay, on thawing in the spring, became semi-liquid and ran until it stood at a slope of from 2 to 1 to 3 to 1. A great deal of it ran over the curb and upon the filter beds which were then being used. This was cleaned off, and then the banks were cut back to a 2 to 1 slope, topped with 1 ft. of loam, and seeded, and the grade of the walk was lowered to the top of the curb.

In order to keep the foot of the embankment in place it was found necessary to excavate the walk to the 4-in. sub-grade and fill in with crushed stone; which furnished sufficient weight to prevent the pressure of the embankment from raising the soft material under the walk.

When the beds were cleaned for the second time it was found that the clay had never been thoroughly removed from them. In order to remove it, the sand to a depth of from 1½ to 3 ins. was taken off and replaced with clean sand. The beds were finally completed about May 1st, 1900.

The following engineers were connected with the work: James S. Haring, M. Am. Soc. C. E., was the Engineer of the Board of Water Commissioners during the design and construction under the first contract. Allen Hazen, M. Am. Soc. C. E., was consulted on the advisability of filtration, and made the original design. Rudolph Hering, M. Am. Soc. C. E., was consulted on the early part of the construction. Louis L. Tribus, M. Am. Soc. C. E., was called in consultation under the second contract. He approved the plans and specifications as modified by the writer, and acted as Consulting Engineer during the construction. The writer was Assistant Engineer under the first contract and Engineer of the Board of Water Commissioners under the second contract.

The cost of the filters is shown in the following table:

Sheet piling in place	$3 300
Sustaining piles in place	1 558
Excavation	5 270
Grading and soiling	1 500
Engineering	3 644
Inspection and tests	713
Rosendale cement concrete in floors	1 958
Portland " " "	780
Rosendale " " walls	1 892
Portland " " slope paving	484
Vitrified brick, slope paving	113
Curb in place	250
Underdrains	347
Filtering material	5 524
Hemlock lumber, capping and floors	838
Yellow pine lumber " " "	465
House over regulating chamber	150
Pipe laying, etc.	58
Miscellaneous	250
Total	$29 094

DISCUSSION.

JAMES S. HARING, M. Am. Soc. C. E. (by letter).—As outlined by the author, the origin of the change of ownership of the water-works of the village of Nyack, from a private to a municipal plant, began with the continued dissatisfaction of the consumers, in the three villages named, with the quality of the water supplied by the private company. Mr. Haring.

In 1872 Commodore William Voorhis, a large property owner in Nyack and South Nyack, constructed, principally for the supply of his own houses in the latter village, a gravity plant, taking the supply from small springs found in the hillside of these villages. Gradually the plant became enlarged by the addition of other consumers, and additional supplies were obtained from springs. In 1884, however, after much expensive and fruitless effort to obtain similar additions, it was found necessary to seek a supply by other means than that of gravity. Examinations of various other sources, including Rockland Lake and the Hackensack River, were then made, and resulted in the selection of the latter as the source of supply.

The Hackensack River originates principally from the outflow of Rockland Lake, and from a stream having its source west of New City, the latter being considered as the purer supply.

In 1895, the Village of Nyack held an election to determine upon the construction of a municipal plant. The vote was favorable, and the Board of Water Commissioners resulted. The writer was at once appointed their engineer, and designed a distribution system which was built in connection with the sewerage system, which caused its rather hasty consideration, as the pipes were laid on a shelf at the side of the sewer trench. A search was then instituted for a supply of water. Various nearby supplies were investigated, and finally a test was made by driven wells in the red sandstone, along the shore of the Hudson River in Upper Nyack, out of which many springs were flowing. These wells were in quarry sites worked many years ago, but long since abandoned. The springs from the various strata had been flowing, without any appreciable loss, for a long time, and seemed to promise results satisfactory, both as to quantity and quality. Three wells, each 8 ins. in diameter, were contracted for at a price per foot which left to the Water Commissioners much latitude as to the depth and the final number of wells to be driven. The depth of the deepest well was 285 ft. and that of the remaining two very much less, when a test was instituted, at first with the barrel pump owned and operated by the contractor, but this having a capacity of only 100 galls. per minute, the writer advised the Commissioners to apply a more thorough test, and succeeding in getting the necessary plant to pump by the use of

Mr. Haring. compressed air. This test was continued without intermission for one week, the quantity pumped averaging more than 100 galls. per minute during the whole of that period. Measurements were made from time to time by which the depression of the water table, both in the well pumped, and in each of the other wells was recorded, and, previous to the constant pumping, the length of time taken by the water-table to recover its normal height was also noted. For six days the test, both as to quantity and quality, seemed to be satisfactory, but upon the seventh day, when it was proposed to end the test, a sample of water taken for analysis was found to be salt. It would be difficult to determine at what time during the test the water became salt. It is a fact that people were using the water pumped during the whole time the test was being made, and that during that time a local chemist was analyzing the water for his own information, but, until the time mentioned, there was no discovery of the fact that the water was salt. The probability is that the salt water came in very gradually as the elevation of the water-table was lowered, the latter finally reaching a point below that of the bottom of the river, the ordinary high water line of which was about 35 ft. distant from the well tested. The shore was a continuation of the red sandstone for a considerable distance out, and was covered not by silt, as had been supposed, but by gravel and coarse sand only.

After this attempt failed, a gravity supply from Spring Valley, about 8 miles to the west, was investigated and practically decided upon. The supply came from a sparsely settled territory and from various small streams, one of which was gauged by the 10-in. meter now in use at the pumping station.

During the early operations of the Water Commissioners it was an open question as to whether or not they would take proceedings to condemn the private water company's plant. They construed the law as being adverse to any attempted negotiations for its purchase at private sale, even though an amicable adjustment could have been arranged, which was doubtful, popular sentiment in the village being adverse to such acquisition; but it was finally determined to take such action because of the immediate revenue to be derived therefrom, and also because of the franchises and distribution in the adjoining villages of Upper Nyack and South Nyack. Proceedings were begun, and a lengthy litigation before Commissioners of Appraisement ended in the acquisition of the private plant, but at a valuation so high that the available appropriation was insufficient to pay the cost of carrying out the gravity supply scheme.

During the time proceedings of condemnation were in progress, the Commissioners had paralleled the mains of the company in the village with a materially larger and more complete system.

One of the elements of the condemnation proceedings was the

attempt of the Water Commissioners to prove the Hackensack River supply to be of objectionable quality. This was, in part, admitted by the company, and the attempt was met by showing that the supply could be filtered at small cost, thereby overcoming that objection. The experts for the company were John Bogart, M. Am. Soc. C. E.; W. F. Whittemore, Assoc. M. Am. Soc. C. E., and Mr. Joseph B. Rider. These experts (with the exception of Mr. Whittemore, who gave testimony on the cost of a filter located on the hill and constructed near one of the reservoirs, but made no recommendation as to site), selected as the site of the filters, not the high-service reservoir, which was especially brought to their attention as a suggested location, but a place near the old pumping station, which was a few hundred feet southeast of the present filters. Later, when Allen Hazen, M. Am. Soc. C. E., was consulted with regard to the construction of a filter and its location, he also advised the present site, or one within a short distance of the site selected, the reasons given for such location being principally its proximity to the pumping station, the facilities for obtaining sand, and that the engineer running the pumps could regulate the filters, thereby saving the cost of additional labor in operation, the approach to the high-service reservoir being somewhat difficult and the cost of additional land at that point being also considerable. The writer calls special attention to these facts because of the criticism following the discovery of the bad bottom alluded to in the paper, and of an attempt made to hold him and the Water Commissioners responsible for an improper location of the filters. Both acted on the advice and best judgment of the expert engineers connected with the condemnation proceedings and their own consulting engineer. Mr. Haring.

When the contract for the construction was let, the price fixed for the excavation was 29 cents per cubic yard, on the supposition by the contractors that the earth, or clay, could be excavated by the use of a centrifugal pump, as was done later by the second contractor in excavating in the curb of the pure-water well. The pump was put on, but the attempt to take out the clay in this manner was a failure; the material, to use the contractors' expression, being "too much like white lead to make it soluble."

Tests were made over both sites before either was selected, one being at the old pumping station, the other at the place chosen. A steel-pointed, 1-in. round iron rod, was used, and was both churned down and driven with a sledge to resistance. The results of these tests were reported to the Water Commissioners, and their attention called to the fact that they were not satisfactory; they were, however, all that were attempted, except the test excavations mentioned later, until the conditions described by the author occurred, after which, as stated by him, tests were made on short cross-sections to the north

Mr. Haring.

and west of the excavation. The results of the latter tests showed a stratification of small boulders and gravel sloping from west to east, and from south to north, the strata seeming to rise to quite near the surface of the meadow at a point about 25 ft. west of the west line of the excavation. This fact led Mr Hering to recommend that the location of the filters be changed by placing them that distance to the west. On the lines of that suggestion the location of the pure-water well was changed, which accounts for its apparently angular position with reference to the filters. The iron rod used in testing the site came to absolute resistance repeatedly in the last test, and upon being withdrawn was frequently found to be much bent, yet, when the clay and gravel was excavated, and on account of the puddling caused by teams passing over it, the bottom of the excavation became semi-liquid, thus proving that nothing short of deep test pits could have shown exactly the character of the bottom at the depth required. Before the site was purchased, test pits were dug to such depth as was possible without pumping appliances, but they were too shallow to afford material information. The geological formations, afterward considered, were generally adverse to the selection of the site.

Complications with the contractors led the Water Commissioners to retain the original location of the filters as shown on the plans, and they were constructed on that site.

From the time bad bottom was discovered, the writer has been under the belief that it would be difficult to prevent separation taking place in the concrete along the edges of the floor adjoining the stringers and board covering. The placing of unequal weight by careless handling of the sand in first filling, or afterward in cleaning the filters, will be found to be a dangerous element in affecting this result; or, with the semi-liquid earth forming the bottom, on which the 1-in. flooring used for the area of the filters alone rests, may accomplish this also by the wave action due to unequal loading, which was constantly in evidence during the operations of the first contractor. Its dangerous character is shown by the spring described in the paper. The first appearance of this spring was the result of a test hole. When the rod was withdrawn a stream of water spouted up some distance above the surrounding bottom, and it in time became an enlarged boiling spring. During the writer's connection with the work, which ended in May, 1898, and while the excavation was free from water, this spring continued to be active, and was only one of several evidences that an underground flow of water was sealed up by the clay bottom only a very short distance below the point reached by the excavation. It would not be surprising to find, when the filters are emptied, that cracks, admitting considerable unfiltered water, exist along these lines, and that in time they may become very troublesome.

Mr. Haring. The writer questions the advisability of the change in Mr. Hazen's plans, from a vertical wall of brick to a slope covering of concrete faced with brick. The embankment material is especially subject to upheaval by frost, the angle of slope and the reduced thickness of the concrete, while it economizes cost somewhat, seems to the writer to do so with the loss of stability.

It may be interesting to note the writer's experience in endeavoring to have brick of proper quality selected for use under the original contract. Mr. Hazen's specifications required the use "of the best quality of hard-burned brick, burned entirely through and of uniform shape and size." The contractor purchased and brought upon the ground brick of a quality which the writer refused to accept for the pumping station structure, and would not consider at all for the filters. He condemned the brick, and the matter was appealed to the Water Commissioners, and by the writer to the Consulting Engineer, Mr. Hazen, who declined to pass upon the matter as not connected with his duties. In this condition matters remained until Mr. Hering was called in. He at once sustained the writer, and the brick were rejected. The writer, believing at all times that vitrified brick with a small percentage of absorption should be used, at least for the facing of the walls exposed to the action of frost by the fluctuation of the water in the filters, insisted upon their purchase and use. This was opposed by some of the Water Commissioners, and consent to their use could not at first be obtained. The writer then personally visited the yards manufacturing the best hard brick at Haverstraw, obtained samples of their brick and submitted them to absorption tests; but finding such proof unavailing, he sent the samples, with one of the inspectors employed on the work, to an ice plant where they were submitted to alternate freezing and thawing. These samples were then submitted to the Commissioners, and, the proof being then no longer to be disputed, the writer was ordered to purchase vitrified brick for the facing of the exposed walls, and the best obtainable hard brick for the interior of the walls. This was done, and all the brick required for the completion of the work was delivered upon the ground under the first contract.

During all the writer's operations at Nyack, the author was his assistant, and the writer desires to bear testimony to his painstaking efforts to bring a difficult problem (for he has had many obstacles to contend with, both in and out of his profession) to a successful conclusion.

Mr. Fuertes. James H. Fuertes, M. Am. Soc. C. E. (by letter).—The manner in which the difficulties encountered in making the excavations for these filters were overcome is interesting and instructive. The method of construction, however, was quite costly, the amount chargeable to the excavation, sheet piling, foundation piles and other earth work, being

Mr. Fuertes. at the rate of about $30 500 per acre of filter surface, out of the total cost of $46 700 per acre for the filters complete.

In the fall of 1895 the writer visited the sewerage works at Newport, Isle of Wight, which were then in construction under the direction of Baldwin Latham, M. Inst. C. E. One of the works was a covered precipitation reservoir, about 70 x 83 ft. inside, divided by longitudinal walls into three basins each 22 ft. wide. The conditions were somewhat similar to those at Nyack, the soil being a slippery clay with a strong tendency to slide and cave, the ground-water level being several feet above the bottom of the reservoir.

The method there successfully adopted was to first build the side-walls, on wide footings, in sheeted trenches. After their completion the interior was excavated, the concrete bottom laid and the partition walls and posts for supporting the roof built upon it.

A description of the method used in building the dome over the filtered water reservoir at Nyack would be of much interest. A little reservoir, somewhat similar to that at Nyack, was built last summer for the Tome Institute, at Port Deposit, Md., under the writer's supervision. This reservoir was circular in plan, 16 ft. in internal diameter, and had a capacity of 5 000 galls. The side-walls and bottom of the reservoir were of Portland cement concrete 6 ins. thick, and the average thickness of the dome, which had a rise of 2 ft., was about 5 ins. Sheets of No. 10, 3-in., diamond, expanded metal were built in the walls, bottom and dome as the concrete was put in place. The dome was turned on a mound of earth, built upon a platform erected inside of the reservoir, and tamped and trimmed to the proper shape. The earth mound was covered with heavy building paper before laying the concrete. When the centering was removed, the dome was found to be perfect in form and smooth on the interior surface, thus justifying the methods used. The total cost was about $250.

Mr. Kaufman. GUSTAVE KAUFMAN, M. Am. Soc. C. E.—The speaker desires to be enlightened as to why it was deemed necessary to locate this filter below high water, and thus require a deep excavation in swampy ground, to do which difficulties might have been expected to be encountered? Why was not the filter placed a great deal higher, and a small centrifugal pump used to deliver the river water to the filter?

In the absence of information or reason to the contrary, it would appear that placing the filter above high water would have been by far the better arrangement. A large amount of money would have been saved in the construction, and the cost of pumping would not have been affected, because the head between the filter and the village would have been reduced by the height of the filter above the ordinary stage of the river.

Mr. Knowles. MORRIS KNOWLES, Assoc. M. Am. Soc. C. E.—Mr. Kaufman's remarks about the advantage of using a centrifugal pump bring to mind an occasion of the use of such a pump for a somewhat opposite purpose, namely, that of pumping water off the surface of the filter.

The author does not state the reason for placing the filter with the water level below that in the river, but in several instances it has been done for the purpose of saving the continuous maintenance cost of pumping.

As is probably well known, the filter at Lawrence, Mass., is placed in such a manner that the river water flows to it by gravity, and, thus far in its history, there has been only one period when this has not been possible. This was during the cold weather in January, 1900, when, for some unusual cause, accompanying long continuous dry weather, like holding the water back in some of the storage reservoirs or mill ponds above, the river was so low that it was not possible to send enough water to the filter to supply the city's use.

Two centrifugal pumps (8-in. and 6-in.), were secured, hurriedly placed in position, and used for a period of about ten days, after which the water level arose, and ever since has been sufficiently high. The 6-in. pump was then returned.

At about this time it was thought advisable to test the usefulness of such pumps for removing the water from the surface of the filter, when desiring to draw down prior to scraping. When the filter is clogged at the surface and needs cleaning, much time has been wasted, after shutting off the inlet water, and before the water has drained down into the body of the sand and the surface is dry enough to work upon. The 8-in. pump, therefore, was equipped with a double suction and discharge, together with suitable valves, so that water could be drawn from the river or from the surface of the filter and discharged to either the filter or the river, as might be desired.

When used as an aid in draining the filter the advantage is so manifest and the saving in time so great, that the wonder is that it was not put into practice before. Thus the pump has two uses, one in case of emergency, and the other, originally secondary, but now the regular one, whenever scraping is necessary; and the investment has proven a profitable one.

Mr. Hazen. ALLEN HAZEN, M. Am. Soc. C. E. (by letter).—This paper describes the application of sand filtration to a small water-works plant. The original plans, which were drawn by the writer, showed the walls of brick, of the full height of the filter, and without the paved slopes. The arrangement, in this respect, was much like that of small filters of the Rumsen Improvement Company, at Red Bank, N. J., which had just been completed, and that of the filters of the Queens County Water Company, at Far Rockaway, Long Island.

Mr. Hazen. The general location of the plant was unquestionably the best. Numerous and serious difficulties would have been encountered in putting the filters on the hills above the distributing reservoirs, and the cost of pumping to filters on higher ground near the pumping station would have represented more than the interest charges on the capital required to put them below the river level. The exact site was selected by Mr. Haring, after making soundings, which showed "very firm" material at depths not exceeding 6 ft. This site was selected because of the convenience of getting a sidetrack from the railroad to it.

The method of construction required by the specifications was to lower the ground-water level at the site to a point below the foundations by underdrains placed low enough to accomplish that purpose, to surround the site, if necessary, with sheet-piling, and to hold the water at that level until after the completion of the structures. This method, apparently, was not carried out at first.

The writer's connection with the work ceased with the completion of the plans and specifications, and at the time which Mr. Haring mentions, in speaking of the brick, he was not in any way connected with the work; and, while he expressed a willingness to pass upon the brick, he was not willing to do so under the conditions suggested by Mr. Haring.

Mr. Tribus. Louis L. Tribus, M. Am. Soc. C. E. (by letter).—The author has presented a very clear and full summary of the main events and chief facts attending the construction of the Nyack sand filters, one of the closing chapters in a series of incidents interesting to the onlooker, but rather trying at times to the parties directly concerned.

Taken with Mr. James S. Haring's discussion, the whole Nyack water question has been outlined. It is a public improvement, which, with the sewerage system, has been followed from the start by difficulties, political, structural and legal.

In the condemnation proceedings, for acquiring the private water plant, the writer was called in consultation for the village, and his valuation closely approximated the award finally made by the arbitrators. Mr. Haring's criticism that the award was excessive is true, perhaps, as to the physical value of the plant acquired, but there was a moral obligation or value which it was only proper to recognize; a value that the experts for the company, whom Mr. Haring mentions, put at many thousands of dollars more than the arbitrators thought wise to grant.

The questions of new supply and filtration were not brought before the writer at the time of the proceedings, only existing conditions being discussed.

About two years later, when the resumption of work was considered on the previously begun and practically abandoned filter plant, the

writer was again called upon, this time to take consulting supervision of construction, the author continuing as the direct Executive Engineer of the Board and Superintendent of the water plant. Mr. Tribus.

Various amendments to the original plans seemed advisable, though the essential points, as designed by Mr. Allen Hazen, remained unchanged.

The springs that broke out in several places in the floor area, naturally gave much concern, and received much attention during construction, as to their flow, head and permanence.

Examination of the floor and walls after the springs were shut off, failed to find any breaks or cracks, even when one of the filters was loaded with its quota of broken stone, gravel and sand, thus bringing nearly the maximum unequal strain on the foundation stratum, the other bed remaining practically unloaded at the time.

To avoid as much of the upward pressure as possible, was one reason for sloping the banks instead of retaining the vertical walls, with consequently heavier embankments; the other, economy, in saving the borrowing of earth beyond that from the filter bed area, and the lesser cost of even the substantial concrete and brick-paved slope over vertical walls of sufficient weight to hold the banks securely.

It is unlikely that as the work stood intact in its construction stage, when the whole was fairly saturated with successive rains, that in its completed, settled, graded and well-drained condition, any harm will come to it, as has been intimated; unless some near-by plot should be excavated to considerable depth for foundations or other purpose; not a likely contingency.

The clear-water well had been partly built at the first construction time, some 10 ft. or so of the brick curbing being in place; in the months intervening before work was again commenced, this curb careened in the soft soil, until very seriously out of plumb. By careful loading on the high side, however, and dredging out beneath the curb on the same side, the whole structure was gradually brought back to line without a crack developing; rather a neat piece of work.

It is to be regretted that regular analyses of the raw and filtered waters are not being made, for, while the general public may rest content with a water freed from its sedimentary matters, and probably, it is supposed from analogous cases, from undesirable bacteria as well, it is of real value to the public to have results known and recorded, whenever conditions have warranted the actual construction of purification works.

Monthly analyses would, in regular conditions of operation, be sufficient, with others made at the time of any special disturbance. This would not entail any great annual expenditure, but might be productive of much good; they certainly would add to the as yet small stock of similar knowledge. Perhaps the authorities will yet see their way clear for such investigations.

Mr. Houston. G. N. HOUSTON, Assoc. M. Am. Soc. C. E. (by letter).—In his discussion, Mr. J. S. Haring calls attention to the unequal loading of the bottom while filling the filters with sand. That no serious trouble should be anticipated from this cause will be evident from the following: The maximum inequality of loading took place when placing the sand. This amounted to 330 lbs. per square foot, or less than the increase of pressure caused by a man walking on the concrete bottom.

Again, as the operation of filling occupied more than a month, any uneven settlement would have occurred while it was in progress, for, when completed, there was no unequal loading. As there was no visible rising of the unloaded portion, it is fair to assume that there was no serious settlement of the loaded portion. The actual load on the bottom is about 900 lbs. per square foot. Assuming the angle of repose of the material as 10°, Rankin's formula gives 2 000 lbs. per square foot as the safe load.

The conditions which led to the changing of the vertical walls to slope paving were as follow: When the plans were being prepared for resuming the work of construction, it was found that the banks of the excavation above the sheeting were eroded to a slope varying from 3 to 1 to 2 to 1, and that the quantity of material to be excavated would not be sufficient for the proposed embankment. As material to make up this deficiency would cost from 60 to 80 cents per cubic yard, it was proposed to change the vertical wall to slope paring, thus saving $\frac{1}{3}$ cu. yd. per linear foot of wall at 70 cents per yard, or 23 cents. This, with 71 cents per linear foot in favor of slope paring, made a total saving of 94 cents per running foot of wall. This slope paving was practically completed in November, 1899, and has been through two severe winters without showing any signs of lack of stability, and is in excellent condition.

The method of building the enclosing walls in sheeted trenches, as described by Mr. James H. Fuertes, was suggested to the first contractor and his engineer during the early part of the work, but was not adopted by them.

The dome of the pure-water well was built on centering composed of 40 ribs radiating from a 2-ft. cylinder at the crown. These ribs were sawed to the proper arc from 2-in. plank, and notched so as to rest on the inner edge of well. The 12-in. dome was built on this, after covering it with small boards. No supports were used below. The cost of this centering, in place, was about $60.

As Mr. Hazen, in his report to the Commissioners, does not discuss the relative merits of supplying the beds by gravity and by low-lift pumps, but simply recommends the first method, the writer cannot state the original reason for so locating the beds. He supposes, however, that it was to avoid the maintenance of the duplicate centrifugal pumping plant which would be necessary. The filters have been

running continuously since they were completed, and are giving the village excellent water. Mr. Houston.

Inasmuch as mention has been made of legal difficulties in connection with the early development of the municipal sewer and water systems of Nyack, it may be of interest to state that a decision has just been given by the Referee, in the case of the Sewer Contractors *vs.* the Village, for recovery for alleged extra work. The contractors recover $800 of $41 000 for which they sued, none of the amount allowed being disputed by the village.

The writer was not employed in connection with the filter construction until after the site had been selected and ground broken. In the light of the discussions, however, it seems evident that the difficulties met in the early part of its construction may be traced to two causes:

1.—The time allowed the engineer in which to make an examination of the proposed site was not sufficient to enable him to determine the exact character of the materials to be excavated and the conditions to be met.

2.—The contract was let to a man with an abundance of good intentions, very little capital and less experience. Had the first contract been let to a thoroughly experienced contractor, the filters would have been completed at a much lower figure.

The importance of periodic bacteriological examinations of the raw and filtered waters is realized by the writer, but he has not yet been able to arrange for them, and, as he has already resigned as Superintendent and Engineer of the Board, he hopes that his successor may soon be provided with the means for carrying them out.

The writer wishes to acknowledge the hearty support and co-operation given him by the Board of Water Commissioners, and also the courteous, careful and workmanlike manner in which the second contractors, Messrs. James Duell & Co., of Tarrytown, N. Y., carried on the work, and which contributed largely to its successful completion.